



HAL
open science

The Prompt ElastoGravity Signals (PEGS): Detection capabilities and limitations of very broadband seismometers

Martin Vallée, Kévin Juhel, Pascal Bernard, Jean Paul Ampuero, Jean-Paul Montagner, Matteo Barsuglia

► To cite this version:

Martin Vallée, Kévin Juhel, Pascal Bernard, Jean Paul Ampuero, Jean-Paul Montagner, et al.. The Prompt ElastoGravity Signals (PEGS): Detection capabilities and limitations of very broadband seismometers. Rencontres scientifiques et techniques RESIF 2019, Nov 2019, Biarritz, France. hal-02446614

HAL Id: hal-02446614

<https://hal.science/hal-02446614v1>

Submitted on 21 Jan 2020

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

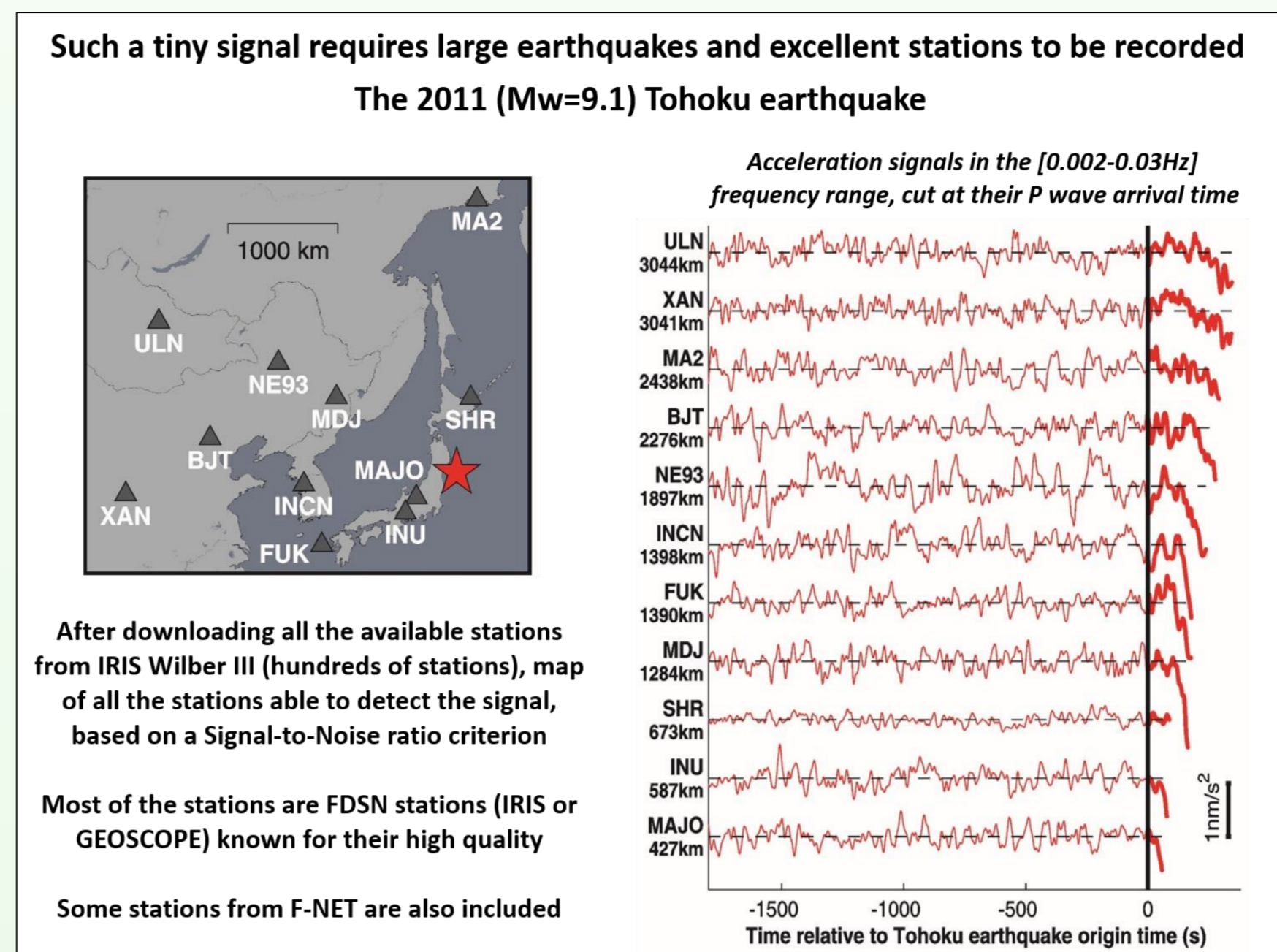


Distributed under a Creative Commons Attribution 4.0 International License

Context

Gravitational perturbations due to mass redistribution associated with tectonic processes :

- Static (final) gravitational perturbations:
 - Known solution for shear or tensile faults in half-space [Okubo et al., 1992]
 - Observed by Earth gravimeters [2003 Tokachi earthquake, Imanishi et al., 2004] and space gravimetry [static gravitational changes of the 2011 Tohoku earthquake detected by GRACE, e.g. Matsuo & Heki, 2011]
- Dynamic gravitational perturbations:
 - Such perturbations also occur immediately after an earthquake [Harms et al., 2015; Montagner et al., 2016]:
 - The Earth masses are perturbed, both at the source location and at the places affected by the transient dilatant/compressive elastic waves
 - These perturbations propagate at the speed of light... even if their signature is small, the quiet period before the P-wave arrival may allow to observe them



But what are exactly these signals that we observe ?

What do we expect to record with a ground-attached seismometer (or gravimeter) ?

Without gravitational changes, gravity only controls the equilibrium position of the mass, and we have :

$$\frac{d^2\xi}{dt^2} + \frac{D}{M} \frac{d\xi}{dt} + \frac{k}{M} \xi = -\frac{d^2u}{dt^2} \quad (1)$$

With Δg , (1) is simply modified as :

$$\frac{d^2\xi}{dt^2} + \frac{D}{M} \frac{d\xi}{dt} + \frac{k}{M} \xi = \Delta g - \frac{d^2u}{dt^2} \quad (2)$$

A seismometer is therefore a seismo-gravimeter, which records, after correction from the instrumental response, the difference between the ground acceleration and the gravitational perturbations

How to compute Δg ?

Let us consider an earthquake in r_s , starting at $t=0$, and generating elastic waves, with the fastest (P) one arriving at T_p at the station in r_0

- At a given time t ($0 < t < T_p$), transient elastic displacements affect the volume V_0^P around the source
- These displacements can be calculated in every point r of V_0^P (use of AXITRA method, moment tensor version) with : $u_i(r, t) = M_{jkm}(t) * G_{ijk}(r_s, r, t)$
- The pre-P gravitational perturbation is controlled by an integral over V_0^P of the form (Dahlen & Tromp 1998):

$$\Delta g^P(r, t) = G \int_{V_0^P} \frac{\rho(r') [u(r', t) - 3(e_{rr} \cdot u(r', t)) e_{rr}]}{|r - r'|^3} dr'$$

But note that there is a gravitational perturbation not only at r_0 , but everywhere in the medium

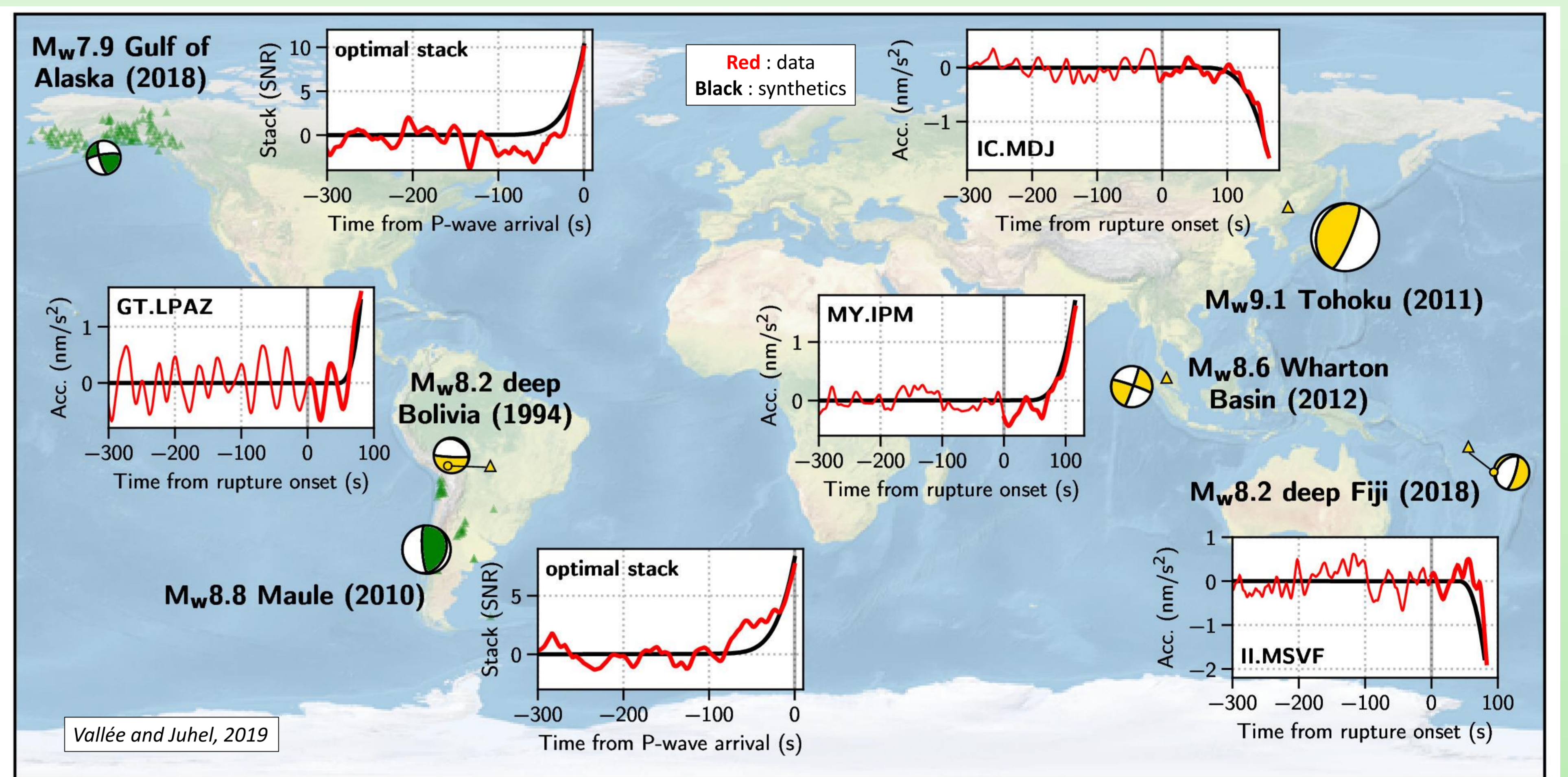
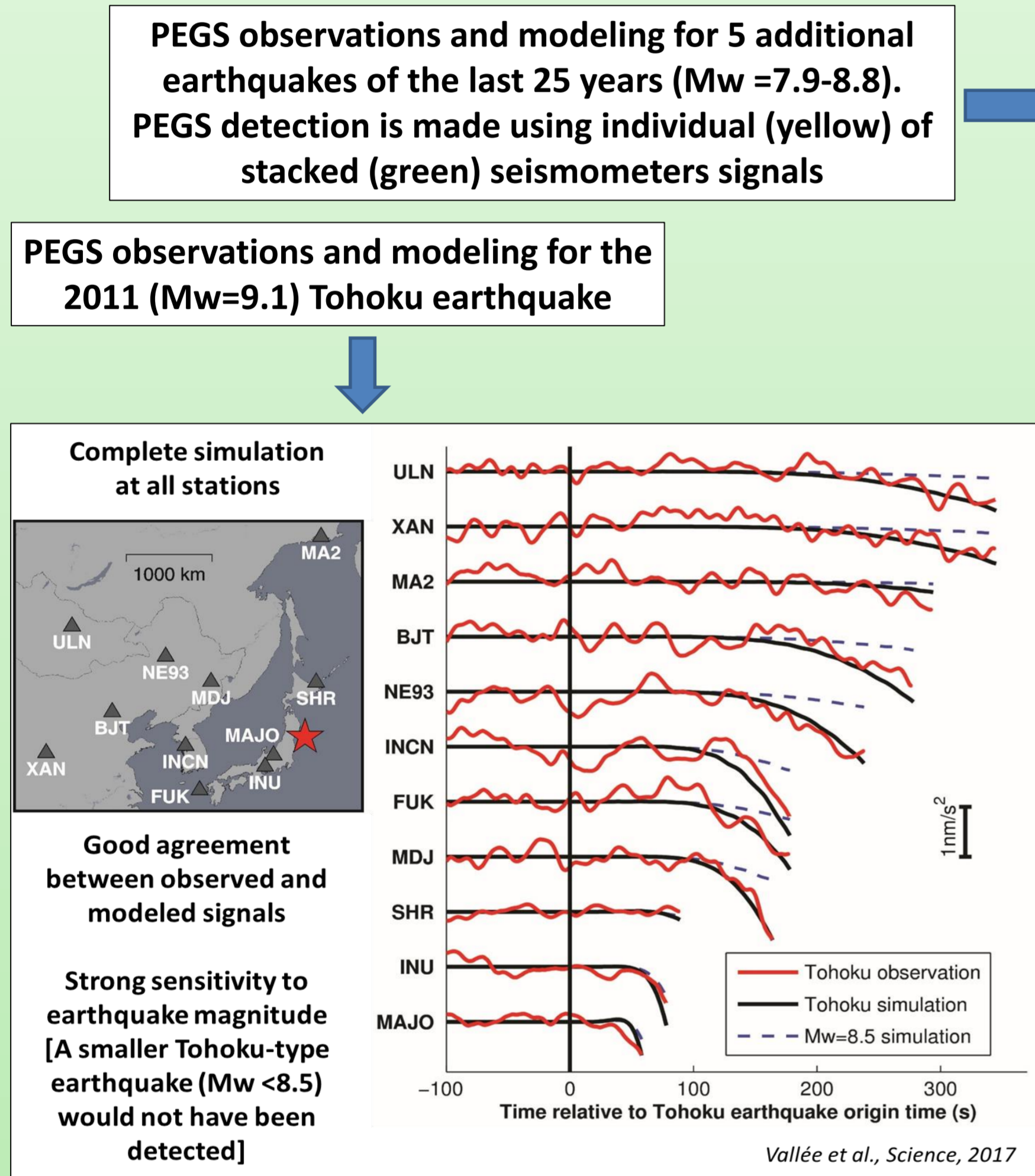
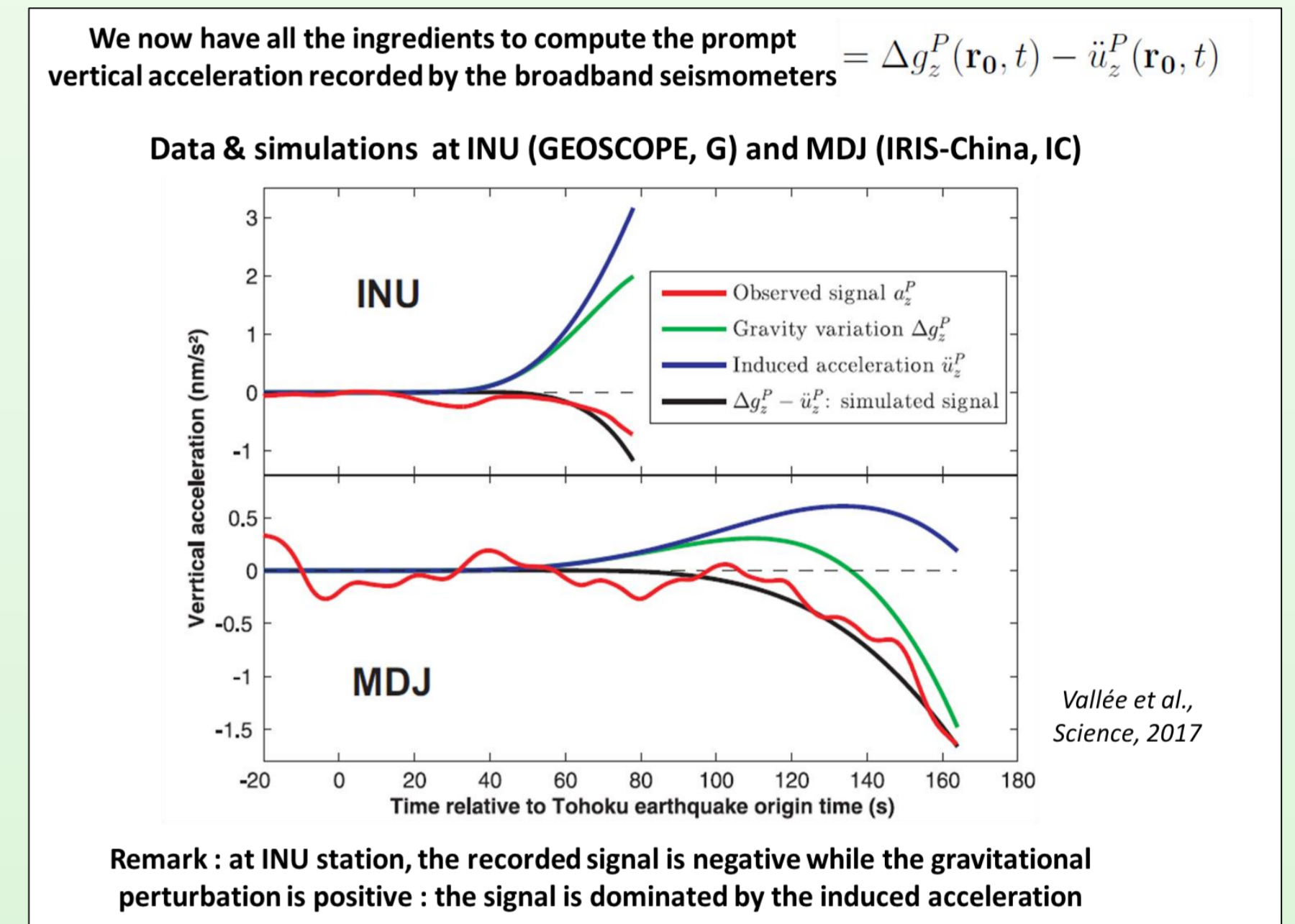
Δg is also a body force acting in the whole medium, which will cause the station to move EVEN BEFORE the arrival of the direct P wave. This can be seen as a try of the Earth to elastically re-equilibrate after the gravitational perturbations.

Concretely, all the gravitational perturbations occurring in the volume V_0^P defined by $V_0^P = \{r' \in V / T^P(r_0, r') < T_p\}$ can generate elastic waves arriving before the hypocentral P arrival at the station

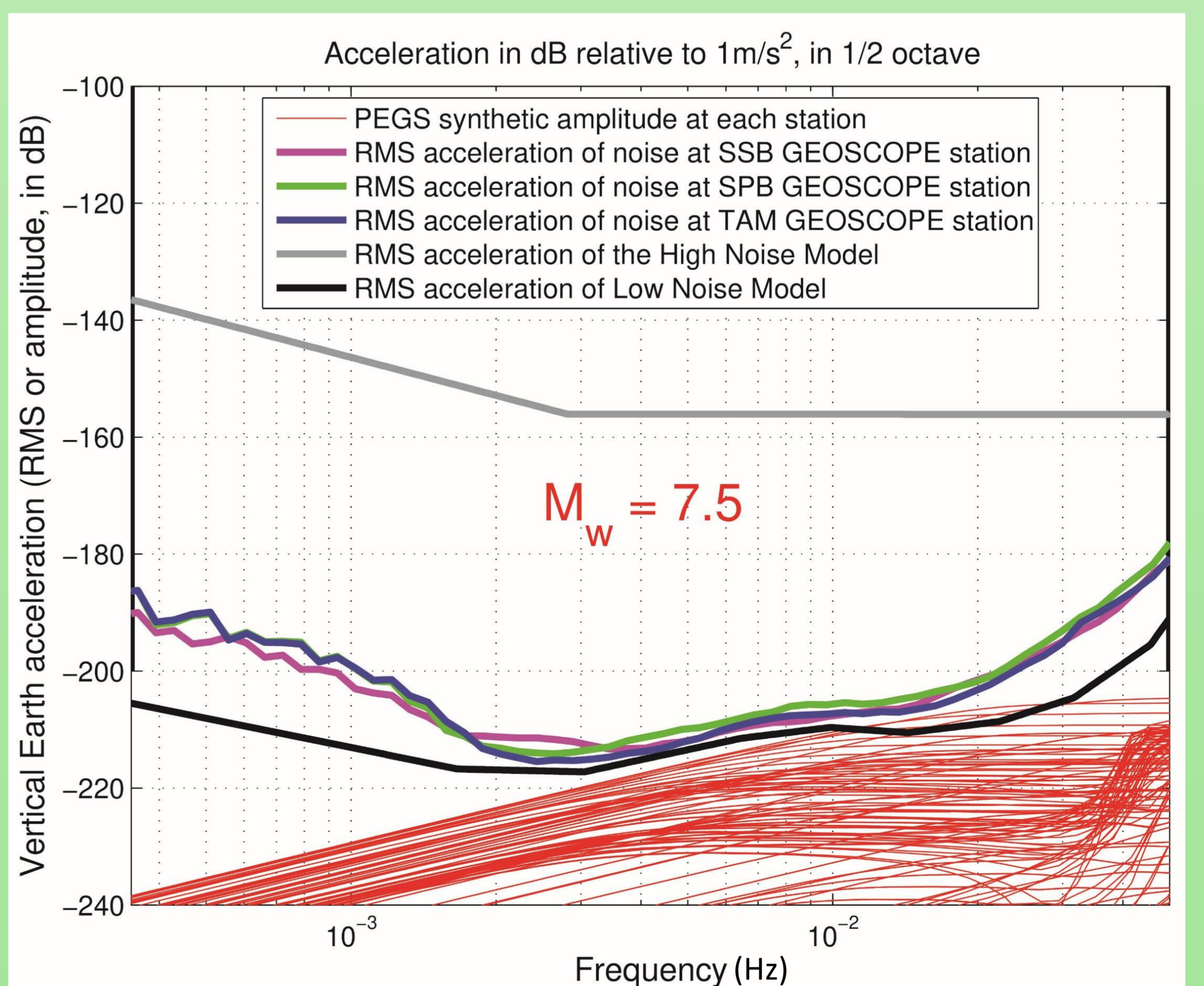
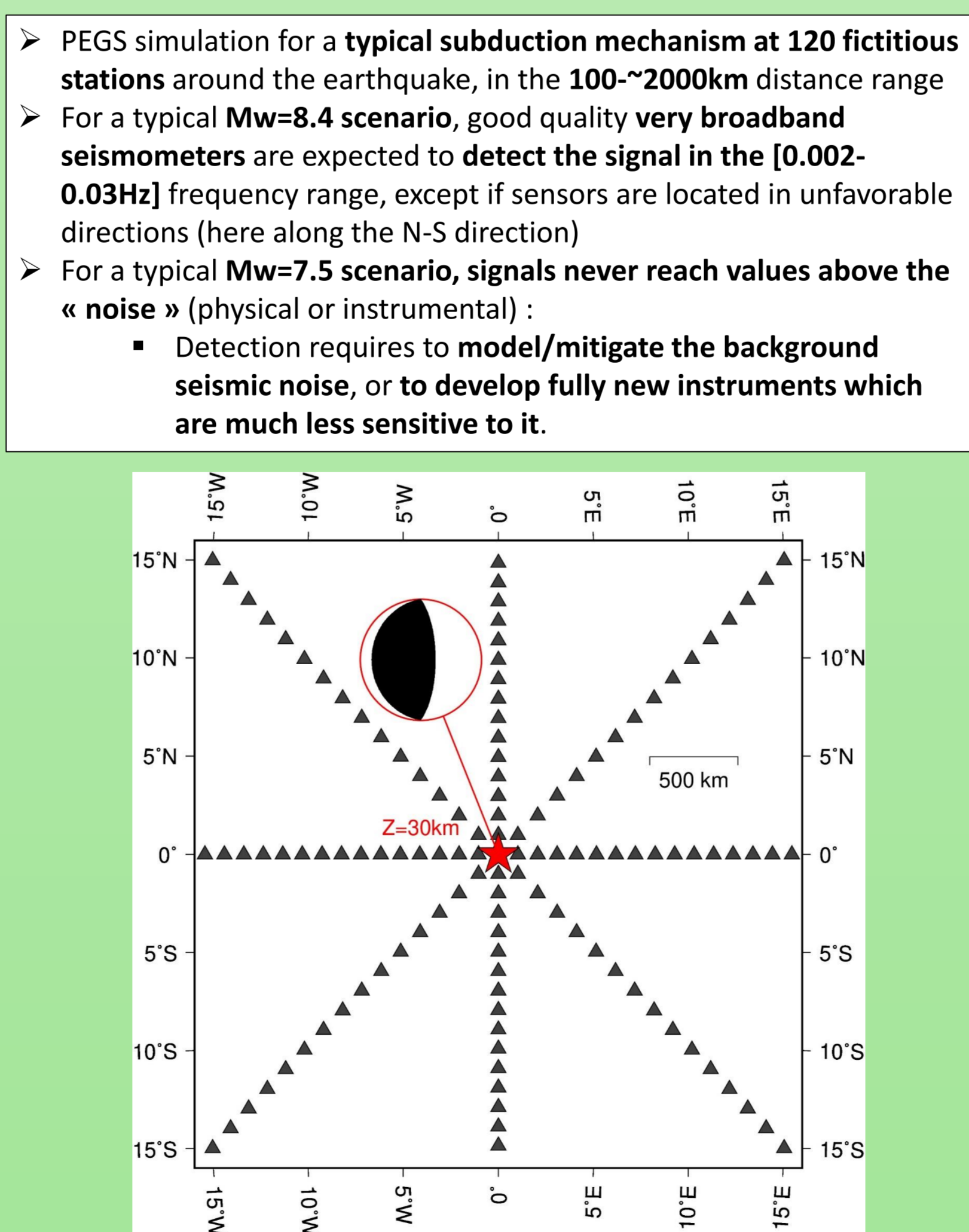
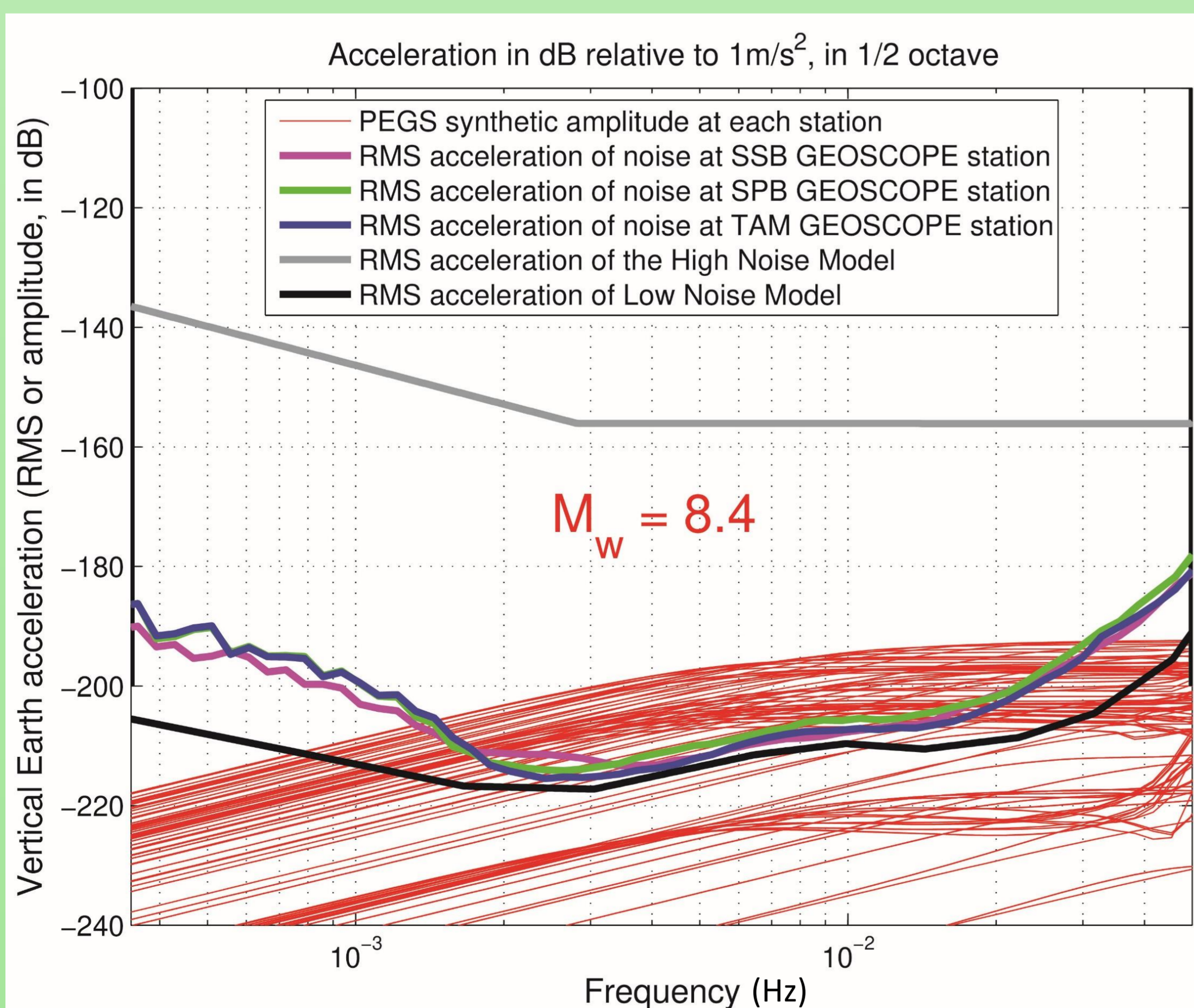
This gravitational-induced acceleration can be computed with the integral

$$\ddot{u}_z^P(r, t) = \frac{d^2}{dt^2} \int_{V_0^P} \rho(r') \Delta g_i^P(r', t) * G_{iz}(r', r, t) dr'$$

AXITRA method (single force)



What are the limitations of PEGS observation with today seismometers ?



References :

Harms, J., J.-P. Ampuero, M. Barsuglia, E. Chassande-Mottin, J.-P. Montagner, S. Somala, and B. Whiting, Transient gravity perturbations induced by earthquake rupture. *Geophys. J. Int.*, **201**, 1416–1425, 2015.

Imanishi, Y., T. Sato, T. Higashi, W. Sun and S. Okubo, A network of superconducting gravimeters detects submicrogal coseismic gravity changes. *Science* **306**, 476–478, 2004.

Matsuo, K. and K. Heki, Coseismic gravity changes of the 2011 Tohoku-Oki earthquake from satellite gravimetry. *Geophys. Res. Lett.*, **38**, L00G12, 2011.

Montagner, J.-P., K. Juhel, M. Barsuglia, J. P. Ampuero, E. Chassande-Mottin, J. Harms and P. Lognonné, Prompt gravity signal induced by the 2011 Tohoku-Oki earthquake. *Nat. Comm.*, **7**, 13349, 2016.

Okubo, S., Gravity and potential changes due to shear and tensile faults in a half-space. *J. Geophys. Res.*, **97**, 7137–7144, 1992.

Vallée, M., J. P. Ampuero, K. Juhel, P. Bernard, J.-P. Montagner and M. Barsuglia, Observations and modeling of the elastogravity signals preceding direct seismic waves. *Science*, **358**, 1164-1168, 2017.

Vallée, M. and K. Juhel, Multiple observations of the prompt elastogravity signals heralding direct seismic waves. *J. Geophys. Res.*, **124**, 2970-2989, 2019.